Online Lab: Vectors and The Force Table

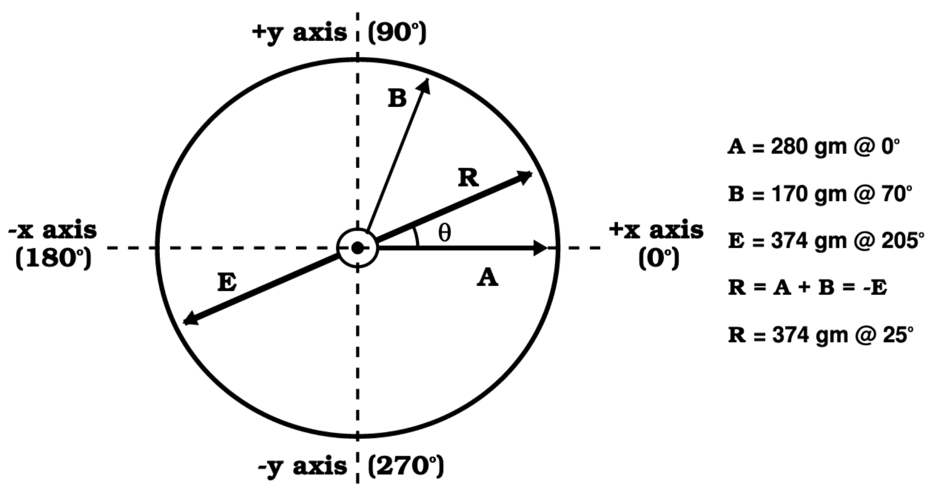
Name: Date:

Instructor: Section:

The Force Table

A force table can be used to determine the sum of two or more vectors and the difference between two vectors. Weights (masses) that represent the magnitude of a given vector are placed on a force table in the proper direction by adjusting the angle of the individual pulleys containing the given weights. Let's associate these weights with vectors $\vec{A}$ and $\vec{B}$. Then the equilibrium weight $\vec{E}$ is determined by trial and error by adjusting the amount of weight on the pulley and the angle placement of the pulley.

The final equilibrium weight vector will be achieved when the central axis of the force table is directly in the center of the center ring to which the pulley strings are attached.Then the **resultant vector** $\vec{R}$ of the addition of vectors $\vec{A}$ and $\vec{B}$ will be the opposite vector to vector $\vec{E}$ as shown in the following figure.



The figure above shows a graphical representation of vectors on a force table. The thickness of the individual vectors are indicative of the amount of weight associated with the vector. In this example, the equilibrium weight adds up to be 374 gm and the pulley is set to 205° to just balance weights associated with vectors $\vec{A}$ and $\vec{B}$.

The resultant vector $\vec{R}$ then must have a magnitude of 374 gm with an angle of $\theta = 25°$, where $25° = 205°$ - 180°. Note that the mass holders each have a mass of 50 grams, and the masses of the holders must be included.

Example: Analytical and Graphical Analysis - 2 Vectors

Find $\vec{R} = \vec{A} + \vec{B}$, Given the vectors: $\vec{A} = 150$ gm @ 50° and $\vec{B} = 200$ gm @ 150° Determine where the Equivalent vector $\vec{E}$ needs to go on the Force Table and how big it needs to be to allow the plastic ring in the middle to not touch the pin sticking up out of the center of the Force Table.

Analytical Analysis

1. For starters, let's break them down into components using trig. This gives us:

$$\vec{A_x} = 150\ cos\ 50° = 96 \text{ gm} \quad \text{and} \quad \vec{A_y} = 150\ sin\ 50° = 115 \text{ gm}$$

$$\vec{B_x} = 200\ cos\ 30° = \text{-}173 \text{ gm} \quad \text{and} \quad \vec{B_y} = 200\ sin\ 30° = 100 \text{ gm}$$

   Note: Since $\vec{B}$ is at 150° we want the angle from the horizontal which in this case is 30° since there is 30° between 180° and 150°.

2. Next, we want to sum everything up in the x-direction and sum everything up in the y-direction to get the total resultant vector $\vec{R}$. *Pay close attention to sign convention.* Up/right = positive. Down/Left = negative.

$$R_x = A_x + B_x = 96 - 173 = -77 \text{ gm} \quad \text{and} \quad R_y = A_y + B_y = 115 + 100 = 215 \text{ gm}$$

$$\vec{R} = \sqrt{(R_x)^2 + (R_y)^2} = \sqrt{(77)^2 + (215)^2} = 228 \text{ gm}$$

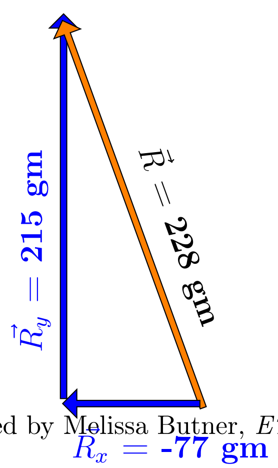
   The vector components ($\vec{R_x}$, $\vec{R_y}$) as well as the resultant vector, $\vec{R}$ is shown in the Figure at the bottom left of the page.

3. Now we want to solve for the angle:

$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right) = \tan^{-1}\left(\frac{215}{-77}\right) = -70° \text{ or } 290°$$

4. So the Equilibrium vector, $\vec{E}$ must be exactly opposite of this resultant vector. This yields:

$$\vec{E} = 228 \text{ gm @ } 290°$$

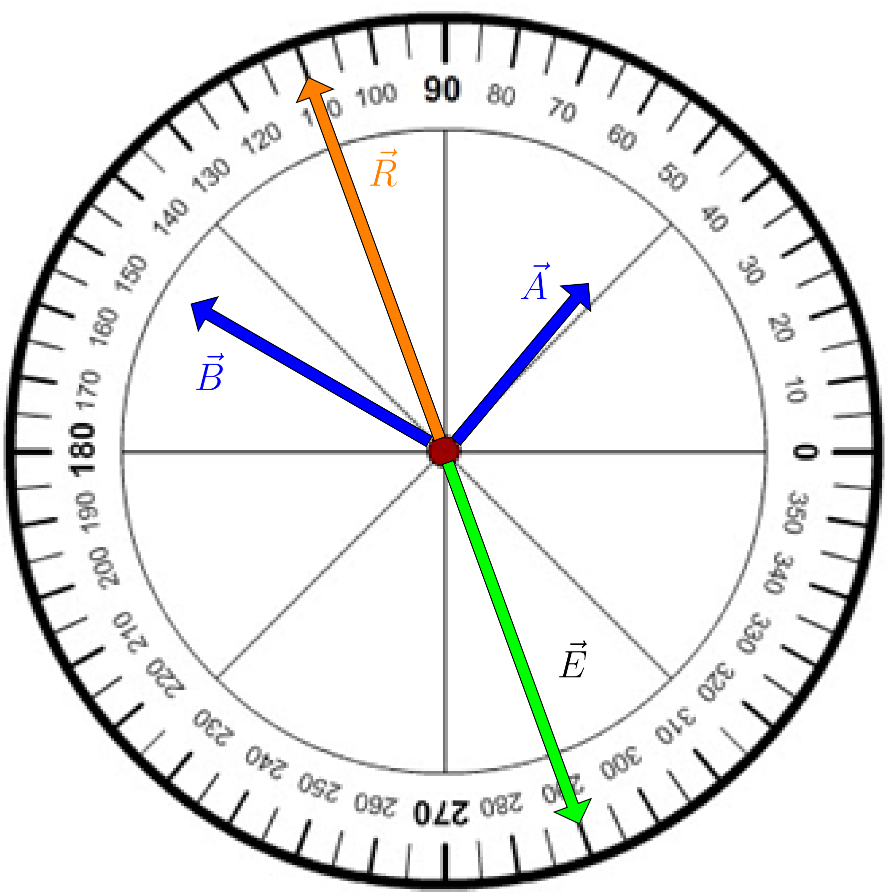


Graphical Analysis

1. Below we have an example Force Table showing 150 gm hung at the 50° degree mark on the force table and 200 gm hung at the 150° degree mark. Recall that on the force table you can imagine an x-axis going from 0° - 180° and then a y-axis going from 90° to 270°.

2. There is a plastic ring in the center of the force table and the two masses (blue arrows below), are hung from the edge of the force table. Now since we are not doing this using an actual Force Table experimentally, we have to imagine the dark red circle in the middle of the Force Table diagram is designed this way. When the masses are hung over the edge of the Force Table, they exert a force in the string and that force is applied to the plastic ring at the center of the Force Table.

3. The goal for this lab is to analytically and graphically determine what the equilibrium mass $\vec{E}$ is and where to place it so that this plastic ring in the middle does not touch the pin sticking up in the center of the Force Table. To do this graphically, we can construct the vector components ($\vec{R_x}$, $\vec{R_y}$) with the resultant vector, $\vec{R}$ like the one in the Figure at the bottom left on page 2. Then using these results we know where to draw each vector on the diagram below at a length roughly proportionate to its magnitude.



$\vec{A} =$ 150 gm @ 50°

$\vec{B} =$ 200 gm @ 150°

$\vec{R} = \vec{A} + \vec{B} =$ - $\vec{E}$

$\vec{R} =$ 228 gm @ 110°

$\vec{E} =$ 228 gm @ 290°

Exploring Vector Components and Vector Addition

1. Go to the following website and **Click** on Explore 2D to open the simulator:
   https://phet.colorado.edu/sims/html/vector-addition/latest/vector-addition_en.html

2. For this part you are going to construct a vector diagram as shown in the Figure below.

3. Select and Drag an $|\vec{a}|$ vector from the vector panel and place its tail at the origin (0,0). Adjust the vector until it has a length of 10 as shown in the Figure below. This length is also called the **magnitude** of the vector.

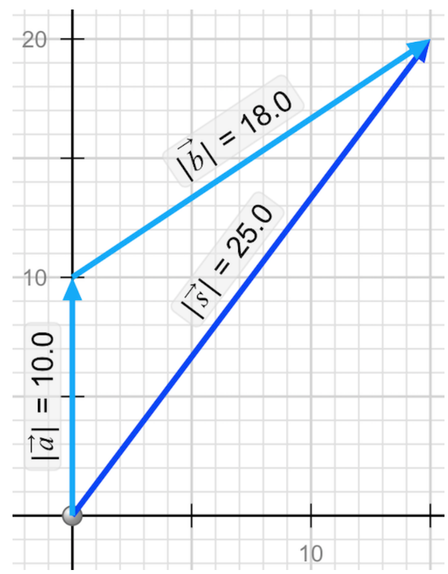
4. Drag out a second vector $|\vec{b}|$ from the vector panel and place its tail at the head of the first vector. Adjust the vector until it points at (15,20) and has a length of 18 as shown in the Figure below.

5. In the panel on the right, Click  to view the x and y components of these vectors.

6. Check the box in the upper right control panel next to **Sum**. A blue vector should appear. This vector represents the vector sum of the first two arrows. This is the sum $\vec{s} = \vec{a} + \vec{b}$

7. Drag the vector so the tail is at the origin and the head touches the head of the second vector.

8. Click on each vector to bring up a table at the top showing its associated values. Complete the tables below.



9. Fill in the table for vector $\vec{a}$ here:

$\lvert\vec{a}\rvert$	θ	a_x	a_y

10. Fill in the table for vector $\vec{b}$ here:

$\lvert\vec{b}\rvert$	θ	b_x	b_y

11. Fill in the table for vector $\vec{s}$ here:

$\lvert\vec{s}\rvert$	θ	s_x	s_y

12. **Take a Photo or Screenshot** - Upload with this Lab Report in D2L.

Analytical Analysis: 2 Vectors

Given the vectors:

$$\vec{A} = 340 \text{ gm @ } 60° \qquad \vec{B} = 280 \text{ gm @ } 270°$$

Find $\vec{R} = \vec{A} + \vec{B}$.

Record Data Here. **Take a photo showing ALL of your work and Upload it with this Lab Report in D2L.**

Data Table (1): 2-Vector Analysis			
	(x-component)		**(y-component)**
$A_x = A\ \cos(\theta)$		$A_y = A\ \sin(\theta)$	
$B_x = B\ \cos(\theta)$		$B_y = B\ \sin(\theta)$	

$R_x = A_x + B_x =$

$R_y = A_y + B_y =$

$R = \sqrt{R_x{}^2 + R_y{}^2} =$

$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right) =$

Analytical Analysis: 3 Vectors

Given the vectors:

$$\vec{A} = 100 \text{ gm @ } 25° \qquad \vec{B} = 200 \text{ gm @ } 115° \qquad \vec{C} = 175 \text{ gm @ } 220°$$

Find $\vec{R} = \vec{A} + \vec{B} + \vec{C}$.

Record Data Here. **Take a photo showing ALL of your work and Upload it with this Lab Report in D2L.**

Data Table (2): 3-Vector Analysis			
	(x-component)		**(y-component)**
$A_x = A\ \cos(\theta)$		$A_y = A\ \sin(\theta)$	
$B_x = B\ \cos(\theta)$		$B_y = B\ \sin(\theta)$	
$C_x = C\ \cos(\theta)$		$C_y = C\ \sin(\theta)$	

$R_x = A_x + B_x + C_x =$

$R_y = A_y + B_y + C_x =$

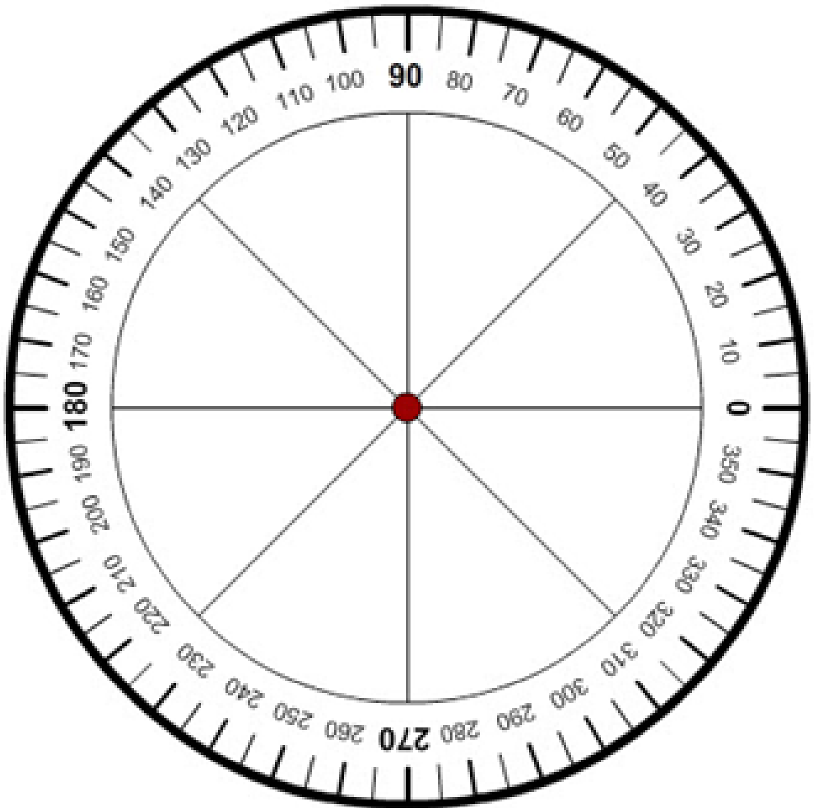
$R = \sqrt{R_x{}^2 + R_y{}^2} =$

$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right) =$

Graphical Analysis: Addition of Two and Three Vectors

Construct the vector components ($\vec{R_x}$, $\vec{R_y}$) as well as the resultant vector, $\vec{R}$ like the one in the Figure at the bottom left on page 2.

Use these results to Draw and Label each vector on the Force Table diagram below.



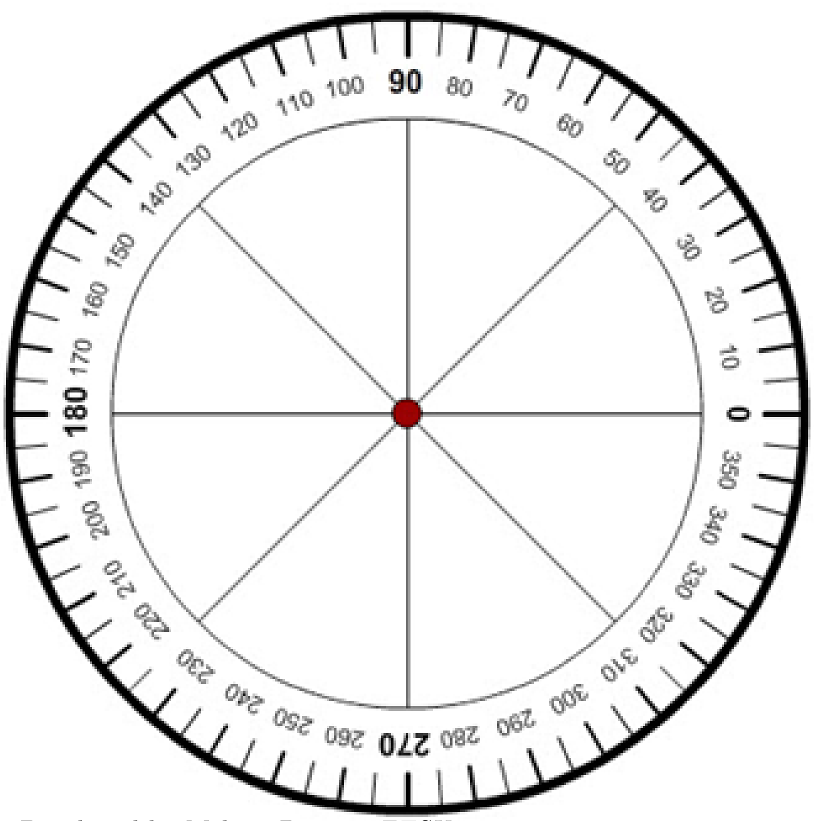
$\vec{A} =$ 340 gm @ 60°

$\vec{B} =$ 280 gm @ 270°

$\vec{E} =$

$\vec{R} = \vec{A} + \vec{B} =$ - $\vec{E}$

$\vec{R} =$



$\vec{A} =$ 100 gm @ 25°

$\vec{B} =$ 200 gm @ 115°

$\vec{C} =$ 175 gm @ 220°

$\vec{E} =$

$\vec{R} = \vec{A} + \vec{B} + \vec{C} =$ - $\vec{E}$

$\vec{R} =$